

SmartNIL[®] with High Refractive Index Glasses and Resists

Introduction

Wafer-level nanoimprint lithography (NIL) has increasingly become a key enabling technology to support new devices and applications across a wide range of markets. In particular complex structures, which typically need direct writing technologies, can be replicated easily and thus allowing to high-volume manufacturing. This is realized by leading manufacturers of augmented reality devices, optical sensors and biomedical chips who are already utilizing the benefits of this technology.

An additional benefit of NIL is that for many devices the replicated layer can be directly used as functional layer in the product. Therefore it is important that the used materials provide according functional properties but also good nanoimprintability and reliability. Nowadays, material suppliers follow this trend especially for photonic applications and provide polymers with broad span of refractive indices. However, there is an enhanced focus on high refractive index (HRI) for e.g. diffractive optical elements. The required materials, resists and glass substrates, are available with refractive indices $n > 1.7$ and are fully compatible with the NIL process chain.

NIL Process Chain for 200 mm / 300 mm Wafers Sizes

To enable mass manufacturing on 200 mm / 300 mm wafers, typically not only the wafer-level NIL but also the mastering has to be considered in order to scale from masters with single devices to fully populated wafers and subsequent reliable replication of working stamps and wafer level production of the devices. This general process flow is depicted in Fig. 1 and schematically illustrates the required process steps.

The shown reference process flow has been used to evaluate in more detail the NIL process with HRI materials. As a starting point an e-beam written master with a single die has been used. This master is replicated multiple times by the EVG770 step and repeat (S&R) NIL system to create a wafer-level master. The resulting S&R master is the basis for subsequent wafer-level manufacturing. The advantage of the S&R mastering is that all devices are a replica from a single device which can be optimized for best performance. Additionally, the S&R mastering is more cost effective and allows easier scaling to 200 mm / 300 mm wafers or even beyond.

The actual production line is completely supported by the fully integrated EVG Hercules NIL system. The system includes all required pre-processing as cleaning, coating and baking as well as EVGs proprietary SmartNIL technology. The system is then used in a first step to manufacture a so-called working stamp which is eventually used for the nanoimprinting of the final devices.

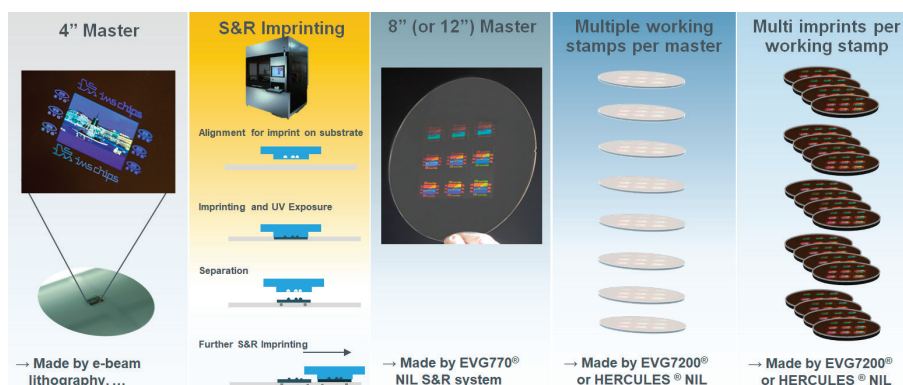
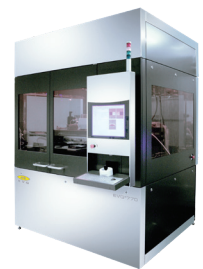


Fig. 1: Schematic overview of the full process chain for high volume manufacturing with SmartNIL on 8" and 12" wafers.

Key Aspects

- Full process chain from single die master to high volume manufacturing
- Step and Repeat Mastering
- Wafer-level Manufacturing
- High refractive index glasses
- High refractive index resists
- Excellent pattern fidelity for nanoimprinted devices
- Robust and scalable processing



EVG[®]770
Step-and-Repeat NIL System



EVG[®]7200
Automated Smart NIL[®] UV-NIL System



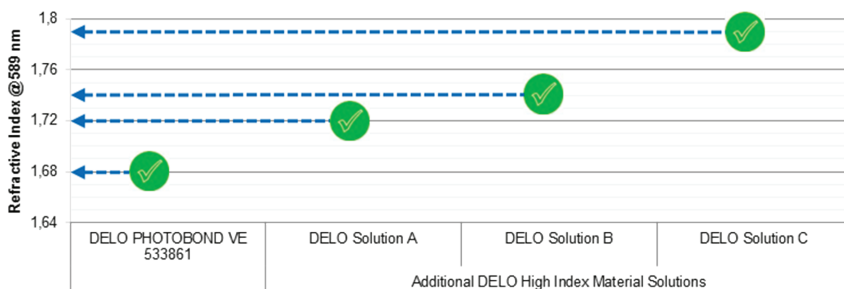
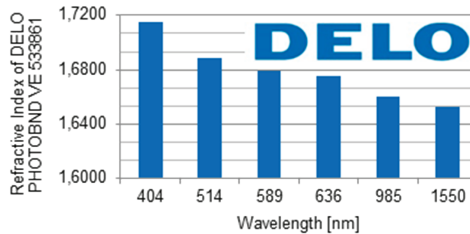
HERCULES[®] NIL
Fully-integrated Smart NIL[®] UV-NIL System

Process Results with High Refractive Index Materials DELO PHOTOBOND VE 533861 on Schott RealView™ 1.7

To achieve the required final device performance it is important to preserve the pattern quality and fidelity throughout the process chain as shown above. This is established for conventional nanoimprint resists which typically don't have particular functional properties and a refractive index $n \sim 1.5$. For HRI applications these newer resists with $n > 1.7$ have been evaluated. Therefore, the same master and manufacturing steps as shown in the reference process flow has been used. The master which depicts the image of a castle which actually consists of pixels based on nanostructures. In Fig. 2 an AFM image of such a pixel is shown, revealing the pillars based nanostructure. For this particular pixel, the pillar dimensions are 186 nm in diameter, 101 nm in height and a pitch of 382 nm. To create the full image with different colours, the sizes of these pillars are modified in a range between 48 nm to 300 nm and the pitch between 140 nm to 500 nm. The total number of the pillars is 2.8 billion. Due the different sizes of the pillars the general performance of the resist and in particular filling properties of the resist can be nicely observed.

For the nanoimprinted structures the HRI resist DELO PHOTOBOND VE 533861 with a refractive index of 1.69 at 589 nm has been used. The imprints were performed on SCHOTT RealView™ 1.7 glass wafers providing a refractive index of 1.7. Schott RealView™ glasses are available also with higher refractive index of 1.8 and even 1.9.

DELO offers solutions for nano imprinting with various refractive index. Besides outstanding imprinting performance these materials are available with different levels of mechanical and thermal stability. Further information can be obtained from DELO Industrial Adhesives.



The AFM image of the SmartNIL imprint in Fig. 3 shows a high quality nanoimprinted structure with excellent pattern fidelity. The measured dimensions are 175 nm diameter and a height of 100 nm with a pitch of 375 nm. This shows that the pattern fidelity is almost perfectly preserved. Slight deviations occurring due to polymer shrinkage can also be easily addressed by an offset in the structure design. Additionally it can be observed, that the resist adheres properly to the surface and all structures are filled nicely. As can be seen in Fig. 4, the imprinted die is replicated without any defects looks bright and colorful. It has to be noted that the colors don't appear realistic as the design is not particularly done for the used materials and the color fidelity depends strongly on the viewing angle.

Summarizing, process readiness of the HRI resist in combination with the HRI glass substrate and the SmartNIL process has been shown for a high volume capable wafer level process.

Materials Overview

E-Beam Master	Etched Silicon	Provided by IMS Chips
S&R Master	Polymer on Silicon	EVG
Working Stamp	Polymer on flexible Backplane	EVG
Imprint Resist	High refractive index polymer	Provided by Delo (PHOTOBOND VE 533861)
Substrate	High refractive index glass	Provided by Schott (RealView™ 1.7)

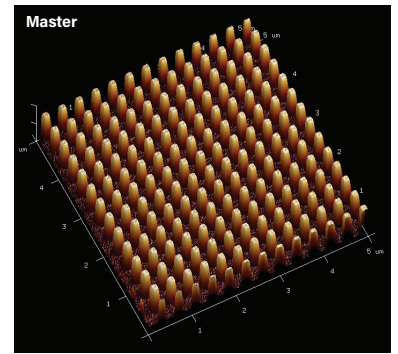


Fig. 2: AFM image of a single pixel on the e-beam written master.

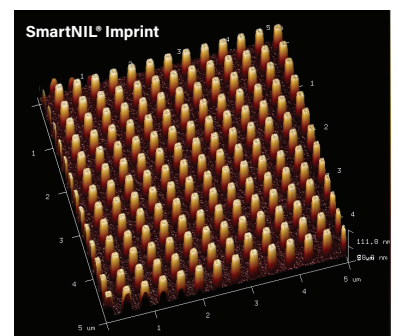


Fig. 3: AFM image of a single pixel on HRI SmartNIL imprint.

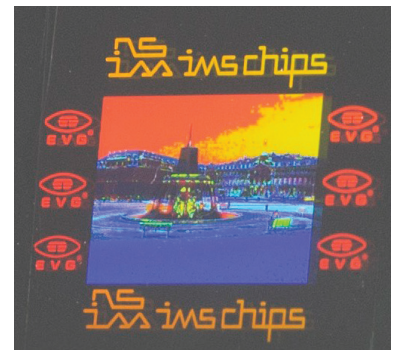


Fig. 4: Single die photography of a HRI SmartNIL imprint under bright light illumination.

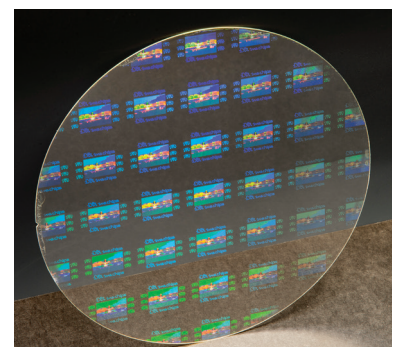


Fig. 5: Full wafer photography of a HRI SmartNIL imprint under bright light illumination.